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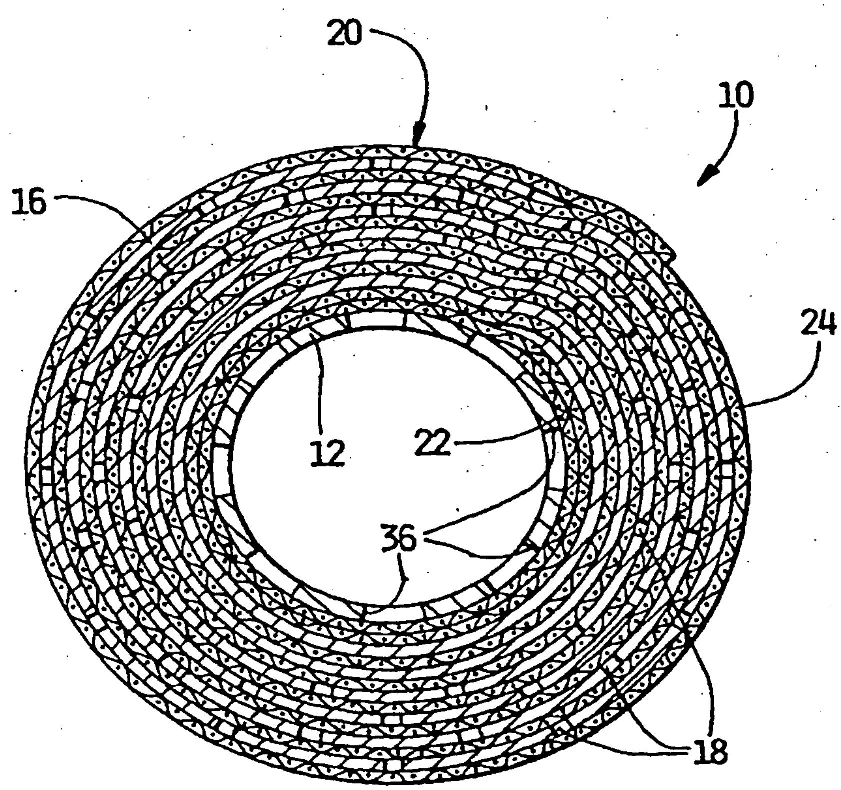
(57) Abstract

A filter (14) including alternating layers of filter medium (16) and diffusion medium (20). The filter provides optimum distribution of fluid over the filtering medium, a reduced pressure drop and an increased filter life, without a reduction in filter rating. The diffusion medium (20) has a first plane of spaced-apart, substantially parallel strands (26) defining first longitudinal passages (28) having a first height dimension and a first width dimension, and a second plane of spaced-apart, substantially parallel strands (30) defining second longidinal passages (32) having a second height dimension and a second width dimension. The strands (30) of the second plane of the diffusion medium are oriented in a non-parallel manner with respect to the strands (26) of the first plane, such that the first and the second planes define lateral openings (34) having side dimensions. The first and the second longitudinal passages include at least one dimension that is smaller than any of the side dimensions of the lateral openings. At least a portion of the layers of filter medium have bypass apertures (18), wherein such portion defines at least one pre-qualifying filter medium layer.



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FILTER AND METHOD OF FILTERING A FLUID

Cross Reference to Related Applications

The present application claims priority to U.S. provisional patent application serial number 60/103,233, filed October 5, 1998, the disclosure of which is incorporated herein by reference.

Background of the Disclosure

1. Technical Field

The present disclosure relates, in general, to a filter, a method of making a filter and a method of filtering a fluid.

More particularly, the present disclosure relates to a filter having alternating layers of non-filtering diffusion medium and filter medium. Some of the layers of the filter medium are provided with bypass apertures, while the remaining layers do not include bypass apertures so that they act as qualifying layers for the filter. Filters according to the present disclosure have been found to provide improved fluid distribution over the filter medium, reduced pressure drop and increased filter life, without a reduction in filter rating.

2. Discussion of Background Disclosures

In general, a filter assembly is used for removing contaminants from fluids, i.e., liquids or gases. Such filter assemblies, for example, are used in chemical and hydrocarbon applications such as polyethylene manufacturing, food and beverage applications, electronic applications such as circuit board construction, coating applications such as high quality spray painting, and industrial applications such as paper manufacturing. Many filter assemblies include a tubular filter cartridge contained in a filter housing. The filter housing includes a sump, wherein the filter cartridge sits, and a head sealing the filter cartridge

within the sump such that the housing acts as a fluid-tight pressure vessel. The filter head includes an inlet between the sump and the filter cartridge, and an outlet aligned with the tubular filter cartridge. Contaminated fluid is pumped into the filter housing through the inlet, and radially inwardly through the filter cartridge to produce filtered fluid, which then exits the filter housing through the outlet.

Normally, such a filter cartridge includes an elongated, tubular, perforated core wrapped with layers of depth filter medium. A typical depth filter medium is a non-woven, porous, melt-blown sheet or sheets of polypropylene micro fibers. The depth filter medium can have a uniform pore structure or a graded or tapered pore structure, whereby the pore size of the depth filter medium decreases in the direction of fluid flow, i.e. from an outer to an inner diameter of the filter. The depth filter medium can also be provided with fibers of varying diameter.

Even with a tapered pore structure and/or varying fiber diameters, however, it has been found that many depth filters actually act as "low area" surface filters, since only one or two of the multiple layers of filter medium within the depth are heavily loaded and plugged with contaminants after use, while the remaining layers are relatively clean (it should be noted that these are general observations, as the performance of a particular filter can depend on the particle size and distribution of contaminants in a fluid to be filtered). When a depth filter cartridge mimics a surface filter and collects contaminants in primarily one layer, the results are an inefficient distribution of fluid over the filter medium, a higher pressure drop for fluid passing through the filter and a lower flow rate capability for the filter. Such filters also tend to have a shorter useful life, and thus must be replaced more often.

A variety of depth filter cartridge configurations have been proposed and/or utilized over the years in efforts to provide improved performance. For example, U.S. Patent No. 4,863,602 to Johnson shows a filter element that includes a plurality of layers of flexible, fluid permeable filtering material, at least one layer of which includes an opening through which fluid may pass, a layer of flexible, fluid-permeable, substantially nonfiltering transport material, and a layer of flexible prefiltering material positioned upstream of the plurality of layers of filtering material to "filter out from the fluid substantially all particles that could otherwise become lodged in the transport material but not to filter out significantly smaller particles."

U.S. Patent Nos. 5,174,895 and 5,015,379 to Drori disclose filter elements featuring at least one coiled filter strip defining first and second butt ends. The Drori filter elements fail to optimally enhance fluid flow while providing extended filter service life. Additional filter designs of background interest are disclosed in U.S. Patent No. 4,877,526 to Johnson; U.S. Patent No. 4,882,056 to Degen et al.; U.S. Patent No. 5,468,382 to Cook et al.; and U.S. Patent No. 5,591,335 to Barboza et al.

Despite the various configurations known in the art, however, there remains a need for a filter cartridge providing improved distribution of fluid over the filter medium therein, a lower pressure drop and long useful life, without reducing the filter rating and that is economical to manufacture and utilize.

Summary of the Disclosure

A filter for filtering contaminated fluid is disclosed herein. A preferred filter includes alternating layers of a filter medium and a diffusion medium, with at least a portion of the layers of the filter medium having bypass apertures and acting as pre-qualifying filter

medium layer(s).

The diffusion medium includes a first plane of spaced-apart, substantially parallel strands defining first longitudinal passages. The longitudinal passages have a height dimension and a width dimension. The diffusion medium further includes a second plane of spaced-apart, substantially parallel strands defining second longitudinal passages. The second longitudinal passages also define a height dimension and a width dimension. The diffusion medium's second plane of strands are oriented in a non-parallel manner with respect to the strands of the first plane such that the first and the second planes define lateral openings. Those lateral openings define side dimensions. The first and the second longitudinal passages are sized such that at least one dimension is smaller than any of the side dimensions of the lateral openings.

Filters of the type disclosed herein demonstrate superior fluid distribution over the filter medium contained therein, and an optimum use of the filter medium. Filters according to the present disclosure, therefore, have an increased life and a lower pressure drop without a reduction in filter rating, and provide more cost effective filtering.

The filters of the present disclosure may be used in methods to filter contaminated fluids in a wide range of commercial applications. Such filters and filtration methods are described in greater detail hereinbelow.

Brief Description of the Drawings

To provide those of ordinary skill in the art to which the present disclosure pertains with an understanding as to how to construct a filter as disclosed and claimed herein, filters according to the present disclosure are described in detail below with reference to the attached drawings wherein:

Fig. 1 shows an isometric side/end view of a filter cartridge of the type disclosed herein;

Fig. 2 shows an enlarged sectional view of the filter cartridge taken along line **2 - 2** of **Fig. 1**;

Fig. 3 shows an enlarged isometric view of a portion of a non-filtering diffusion layer and a non-qualifying filter layer of the filter cartridge of **Fig. 1**;

Fig. 4 shows a sectional view of the diffusion layer and the non-qualifying filter layer of the filter cartridge of **Fig. 1** taken along line **4 - 4** of **Fig. 3**;

Fig. 5 shows a sectional view of the diffusion layer and the non-qualifying filter layer of the filter cartridge of **Fig. 1** taken along line **5 - 5** of **Fig. 3**;

Fig. 6 shows a sectional view, similar to **Fig. 4**, of a diffusion layer and an alternative filter layer for use with the filter cartridge of **Fig. 1**;

Fig. 7 shows a top plan view of a continuous sheet of non-filtering diffusion medium and sheets of filter medium being wound onto a core to form a filter cartridge of the type shown in **Fig. 1**;

Fig. 8 shows an isometric, exploded view of a continuous sheet of non-filtering diffusion medium and sheets of filter medium prior to being wound onto a core to form an alternative filter cartridge according to the present disclosure;

Fig. 9 shows a sectional view, similar to **Fig. 2**, of a further filter cartridge according to the present disclosure; and

Fig. 10 shows an isometric view of a continuous sheet of non-filtering diffusion medium, a sheet of filter medium, and spaced-apart strips of filter medium being wound onto a core to form an alternative filter cartridge according to the present disclosure.

Detailed Description

Referring to **Figs. 1** through **5**, a filter cartridge **10** according to the present disclosure includes an elongated, porous, rigid core **12** having a multiplicity of openings **36**, and an elongated, hollow filter **14** coaxially mounted on the core **12**. Annular end caps **38** are bonded to the ends of the filter to prevent contaminated fluid from by-passing the filter **14**.

The filter **14** includes at least one sheet of filter medium **16**, with at least a portion of the filter medium **16** including bypass apertures **18**, and a sheet of non-filtering diffusion medium **20**. The sheets of the filter medium **16** and the diffusion medium **20** are wrapped, or coiled, to form alternating layers of filter medium and diffusion medium extending from an innermost layer **22** to an outermost layer **24** of the filter **14**. In a preferred embodiment, the diffusion medium **20** is bonded to itself at the outermost layer **24** to prevent the filter **14** from unwinding or unwrapping during shipping, handling and use. As such, the diffusion medium **14** defines the outermost layer **24** of the filter **14**.

1. The Diffusion Medium

The diffusion medium **20** includes a first plane of spaced-apart parallel strands **26** forming longitudinal passages **28**, and a second plane of spaced-apart parallel strands **30** forming longitudinal passages **32**, as illustrated by arrows **f1**, **f2** in **Fig. 3**. The strands **30** of the second plane are oriented such that they are not parallel with the strands **26** of the first plane, such that the first and the second planes form lateral openings **34**. In a preferred embodiment, strands **26** are substantially perpendicular to strands **30**. The longitudinal passages **28**, **32** are preferably smaller in at least one dimension as compared to the smallest dimension of the lateral openings **34**. In particular, a height **h** of the longitudinal passages

28, 32, as best shown in Fig. 4, is preferably smaller than the length or width of the lateral openings 34.

The longitudinal passages 28, 32 of the diffusion medium 20 distribute the fluid to be filtered through flow channels f1, f2, such that the diffusion medium 20 allows for, and assists in, the longitudinal, or circumferential and/or axial, flow of the contaminated fluid within the filter 14 between the innermost layer of the filter medium 16 and the core 12, and/or between adjacent layers of the filter medium. Such longitudinal flow assists in minimizing the pressure drop across the filter cartridge 10 and in dispersing the filtration function. The diffusion medium 20 is preferably positioned between the core 12 and the innermost layer of the filter medium 16 to facilitate the passage of fluid through the openings 36 in the core 12. In a preferred embodiment, the core 12 is surrounded by a plurality of diffusion medium 20 layers to provide a collection area for the flow prior to exiting through openings in the core 12. Positioning of the diffusion medium 20 between adjacent layers of the filter medium 16 similarly maximizes the use of the filter medium surface area within each layer for contaminant loading, thereby reducing pressure drop and optimizing filter medium usage to extend filter life.

In preferred embodiments, the dimensions of the lateral openings 34 and the longitudinal passages 28, 32 of the diffusion medium 20 are purposely selected to be substantially larger than any contaminant to be filtered from the contaminated fluid. As a result, the diffusion medium 20 does not act as a filter. Since the diffusion medium 20 does not act, and is not used, as a filter to trap contaminants, the diffusion medium does not substantially contribute to the pressure drop across the filter 14, and in fact minimizes the pressure drop by providing unobstructed flow channels f1, f2 for contaminated fluid. In

addition, the diffusion medium **20** provides structural rigidity and protects the filter medium **16** from damage. The filter **14** is advantageously provided with an extra outer layer of the diffusion medium **20** to add support and protection to the filter **14**.

The diffusion medium **20** is made from a suitable material that is temperature and fluid compatible with the filtering application to be carried out. Preferably, the diffusion medium **20** is made of a suitable thermoplastic. For example, for lower temperature filtering applications (i.e., below 180° F), the thermoplastic can comprise polypropylene, while for higher temperature applications (i.e., above 180° F) or chemical compatibility with different fluids, the thermoplastic can comprise nylon, polyester, or melt-processible fluoropolymer.

The diffusion medium **20** preferably comprises thirty thousandths of an inch (30 mils) thickness, bi-planar strand orientation (17 mil strand size), twelve strands per inch, polypropylene extruded netting. Such netting is available, for example, under the trademark Plastinet®, manufactured by Applied Extrusion Technologies, Inc. of Middleton, Delaware, or Naltex®, manufactured by Nalle Plastic, Inc. of Austin, Texas. The strands **26** of the first plane may be transversely oriented with respect to the strands **30** of the second plane such that the two planes form generally square or diamond-shaped lateral openings **34** having side dimension of about 0.066 inches. Thus, a preferred diffusion medium **20** exhibits a ratio between lateral opening **34** side dimensions to lateral passage **28, 32** height (hereinafter "Side-to-Height Ratio") of approximately 66:17 or 3.9:1. In addition, the sheet of the diffusion medium **20** is oriented so that the square lateral openings **34** form diamonds between ends **40, 42** of the cartridge **10** to advantageously distribute flow over the tubular filter.

Alternative netting dimensions may be utilized according to the present disclosure. In preferred embodiments, however, to ensure that the diffusion medium **20** does not function as a filter, the Side-to-Height Ratio should be greater than about 1.5:1 and preferably greater than 3:1. As noted hereinabove, a preferred diffusion medium **20** according to the present disclosure exhibits a Side-to-Height Ratio of about 4:1.

2. The Filter Medium

According to preferred embodiments of the present disclosure, the filter medium **16** is preferably of the depth filter type, wherein contaminants are trapped within the medium, as opposed to on an outer surface of the medium. A preferred depth filter medium **16** is comprised of one or more sheets of non woven thermoplastic micro fibers. The non woven thermoplastic micro fibers may be melt blown, spunbond, carded, or hydroentangled, for example. For lower temperature filtering applications (i.e., below 180° F), the thermoplastic can comprise polypropylene, for example, while for higher temperature applications (i.e., above 180° F) or chemical compatibility with other fluids, the thermoplastic can comprise nylon, polyester or melt-processible fluoropolymer, for example.

Furthermore, filter medium suitable for use in accordance with the present disclosure includes porous membrane, such as a cast nylon porous membrane available as Zetapore® from CUNO, Incorporated of Meriden, CT. Other filter medium suitable for use in accordance with the present disclosure includes wet laid paper made with such raw materials as glass or cellulose. An example of a suitable wet laid filter medium is TSM®, available from CUNO, Incorporated of Meriden, CT. Woven material can also be incorporated as the filter medium in accordance with the present disclosure.

The filter medium **16** is preferably provided in discrete sheet form, as opposed to being melt blown directly onto the diffusion medium, for example, such that the sheets can be inspected prior to being incorporated into the filter **14**. The use of discrete sheets of depth filter medium **16** has been found to simplify quality control inspection of the filter medium and make the physical properties of each filter cartridge **10** more consistent. The ability to control the consistency of the physical properties of the depth filter medium **16** provides a unique ability to achieve sharp, well-defined, and optimized control over the removal efficiency and dirt capacity of the resulting filter cartridge **10**. It should be understood, however, that a filter in accordance with the present disclosure could be provided with a single continuous sheet of filter medium.

According to preferred embodiments of the present disclosure, the porosity of the filter medium **16** may be constant between the inner and the outermost layers **22**, **24** of the filter **14**. Alternatively, a filter medium **16** can be provided having a porosity that varies between the outermost layer **24** and the innermost layer **22** of the filter, e.g., a filter having a tapered or graded pore structure. If, as preferred, the filter medium **16** comprises melt-blown, non woven polypropylene micro fibers, the pore size and/or fiber diameter geometries can be constant or varied between the outermost layer **24** and the innermost layer **22** of the filter. A depth filter medium **16** having a relatively uniform pore size and fiber geometry is shown in **Figs. 4** and **5**, while a filter medium **17** having a decreasing pore size is shown in **Fig. 6**. The sheets of depth filter medium can also be processed, e.g., calendared or compressed, to change its porosity in instances where it is desired to utilize filter medium porosity to achieve desired filtration results.

3. The Bypass Apertures

According to preferred embodiments of the present disclosure, a portion of the depth filter medium **16** includes a multiplicity of spaced-apart bypass apertures **18**. Preferably, the bypass apertures **18** extend from the outermost layer **24** of the depth filter medium **16** for a distance equal to between fifty and eighty-five percent (50% - 85%) of the overall radial distance from the outermost layer **24** to the innermost layer **22** of the filter **14**. Most preferably, the bypass apertures **18** are extend to about sixty-six percent (66%), i.e. two-thirds, of the radial distance from the outermost layer **24** to the innermost layer **22** of the filter **14**.

According to the preferred embodiments, the filter medium layers **16** closest to the core **12** do not include bypass apertures such that all of the fluid must pass through the inner layers. In this way, the innermost layers of the filter medium **16** act as qualifying layers for the filter **14**, thereby permitting the filter **14** to be rated based upon the particle retention of the qualifying layers. In like manner, the outer layers of filter medium **16** having the bypass apertures **18** act as pre-qualifying layers.

It should be noted, however, that if the filter cartridge **10** is to be used within a filter assembly wherein contaminated fluid is forced to flow radially outwardly therethrough, i.e., the orientation of the fluid flow through the filter cartridge **10** is to be reversed relative to the embodiments described heretofore, then the bypass apertures **18** may be advantageously provided to extend from the innermost layer of the depth filter medium **16** to a radial distance of about fifty to about eighty-five percent (50% - 85%) of the overall radial distance between the innermost layer **22** and the outermost layer **24** of the filter **14**. When so oriented, the inner layers of the filter medium **16** will act as pre-qualifying layers, while the

outer layers act as the qualifying layers.

It should also be noted that a filter according to the present disclosure is not limited to the coiled designs shown in the attached figures. The unique elements of the present disclosure, i.e., alternating layers of filter and diffusion mediums as disclosed and claimed herein, can be utilized in other filter structures, such as a pleated filter cartridge or a filter bag.

The bypass apertures **18** may be uniformly spaced-apart in predetermined patterns, and provided as generally circular openings. The geometry and relative sizes of the apertures **18**, however, may be advantageously varied, e.g., circular holes and elongated slots of varying sizes are contemplated, and combinations thereof. The apertures **18** may also be provided as slits, cuts or perforations in the filter medium **16**, and such slits, cuts or perforations may be designed such that they do not fully open until a predetermined pressure differential is created across the filter cartridge **10**. In addition, the multiplicity of bypass apertures may be provided in a number of different patterns, e.g., linearly aligned, diagonally aligned, or random, and the pattern(s) may vary from layer to layer of the filter medium **16**.

During operation with a filter cartridge **10** in which the fluid flow is radially inward, contaminated liquid or gas passes laterally (i.e., radially) inwardly through the lateral openings **34** in the outermost layer(s) of the diffusion medium **20**. The contaminated liquid or gas then contacts an outermost layer of the filter medium **16**. Contaminated liquid or gas that does not immediately pass through the outermost layer of the filter medium **16** or the bypass apertures **18** in the filter medium may be directed longitudinally, or substantially parallel with respect to the outermost layer of the filter medium **16**, through the longitudinal passages **28, 32** of the diffusion medium **20**, depending on the relative resistance to flow.

For each of the non-qualifying layers of filter medium **16**, the bypass apertures **18** allow a portion of the fluid to pass therethrough instead of passing through the filter medium of that particular layer. After passing through one of the non-qualifying layers of filter medium, the fluid passing through the bypass apertures **18** and the fluid passing through the filter medium **16** are re-mixed and diffused in the diffusion medium **20** before being filtered by the next layer of filter medium **16**. The bypass apertures **18**, accordingly, help utilize all available filter medium **16** and help to reduce the pressure drop through the filter **14**. Preferably, the bypass apertures **18** provide uniform contamination loading of the non-qualifying layers of filter medium **16**.

4. Performance

The combination of the filter medium **16**, the diffusion medium **20** and the bypass apertures **18** in the manner described hereinabove has been found to have the synergistic effect of simultaneously increasing filtration capacity and minimizing pressure drop across the filter cartridge **10**, without reducing the filter rating. This synergistic effect is demonstrated by the following test results:

- A filter cartridge ("Test Cartridge 1") utilizing non-filtering diffusion medium along with filter medium, but without bypass apertures, exhibits a filter life about two times greater than a "control" filter cartridge having neither non-filtering diffusion medium nor bypass apertures.
- A filter cartridge ("Test Cartridge 2") utilizing bypass apertures along with filter medium, but without diffusion medium as described herein, does not exhibit a greater filter life than the control filter cartridge.
- A filter cartridge **10** ("Test Cartridge 3") according to the present disclosure

utilizing non-filtering diffusion medium **20** having a Side-to-Height Ratio of about **4:1** and relatively uniform bypass apertures **18** extending about two-thirds of the radial distance from the outermost layer to the innermost layer, exhibited three to four times the filter life of the control filter cartridge.

- A filter cartridge **10** ("Test Cartridge 4") according to the present disclosure utilizing both the non-filtering diffusion medium **20** and bypass apertures **18** as described for Test Cartridge 3, and wherein the number of bypass apertures **18** increases towards the outer diameter of the filter **14**, exhibits from four to five times the filter life of a control filter cartridge.
- Test Cartridge 4 exhibits from two and a half to three times the filter life of a filter cartridge utilizing both non-filtering diffusion medium and bypass apertures, wherein the number of bypass apertures increases towards the outer diameter of the filter, and wherein the diffusion medium comprises a polyolefin spunbond web available as POWERLOFT® media from Kimberly-Clark Corporation of Roswell, GA.

The advantageous performance described above for Test Cartridges 3 and 4 is confirmed by visual inspection. Upon dissection of the Test Cartridge 3 after testing, the filter medium **16** displayed contaminant loading to a radial depth from the outermost layer **24** of about fifty percent (50%) of the filter **14**. In comparison, only the outermost layer of filter medium displayed contaminant loading in Test Cartridge 1. Thus, the combination of the diffusion medium **20** and the bypass apertures **18** as described for Test Cartridges 3 and 4 provides a synergetic effect that was not to be expected based upon the performances of Test Cartridges 1 and 2 possessing either non-filtering diffusion medium or bypass

apertures, respectively, but not both.

The testing procedure included a single pass test at a flow rate of three gallons per minute of water containing between about 0.39 to about 1.0 grams per gallon of contaminant. Two standard contaminants were used: 0-30 micron contaminant (ISO COARSE, A.T.D. 12103-1, A4, available from Powder Technologies, Inc. of Burnsville, MN) and 0-10 micron contaminant (A.T.D. nominal 0-10 microns, also available from Powder Technologies, Inc). All of the filter cartridges tested had an outer diameter of about 2.5 inches and were about 10 inches long. The life of a filter for purposes of the tests is defined as the amount of contaminant challenged for the pressure drop across the filter to increase by 20 psid due to contaminant loading in the tested filter.

5. Examples

Additional exemplary filters made in accordance with the present disclosure are described hereinbelow. However, these exemplary filters are merely illustrative of filters that may be made according to the present teachings, and are not intended to be limiting thereof.

Example I:

Referring to **Fig. 7**, an exemplary filter **48** according to the present disclosure is shown. The filter **48** includes a single continuous sheet of diffusion medium **20** comprising thirty thousandths of an inch (**30** mils), bi-planar strand orientation (**17** mil strand size), twelve strands per inch, polypropylene extruded netting. The Side-to-Height Ratio of such diffusion medium is approximately **4:1**. The filter material, which comprises melt-blown, non woven polypropylene micro fibers, is provided in a plurality of discrete sheets **16a, 16b, 16c**. The plurality of sheets of filter medium **16a, 16b, 16c** exhibit substantially equal and

consistent pore size and fiber geometries. As shown, the ends of the sheets **16a, 16b, 16c** are overlapped. The overlapping ends of the sheets **16a**, **16b**, **16c**, however, are not sealed or bonded since the tightly wound sheet of the diffusion material **20** provides an adequate seal between the overlapping ends of filter medium.

Inner (with respect to the core **12**) sheets **16a** of the depth filter material do not have bypass apertures, while outer sheets **16b**, **16c** of the filter material have bypass apertures **18** (it should be noted that only the ends of the non-perforated qualifying layers **16a** need to be overlapped). The outermost sheets **16c** of filter material are preferably provided with more numerous bypass apertures **18** than the intermediate sheets **16b**.

The bypass apertures 18 in sheets **16b**, **16c** are formed by perforating the sheets **16b**, **16c** prior to winding or coiling the sheets of diffusion medium **20** and filter medium **16a**, **16b**, **16c**. In particular, sheets **16b** are provided with circular perforations having diameters of about 5/32 inches, which are arranged in straight rows at intervals of about 1.2 inches, and wherein the rows are aligned and spaced at intervals of about 1.2 inch. Sheets **16c** are provided with circular perforations having diameters of about 5/32 inches, which are arranged in straight rows at intervals of about 1.2 inches, and wherein the rows are staggered and spaced at intervals of about 0.6 inches. In sum, sheets **16c** contain almost twice as many perforations **18** as do sheets **16b**. In general, it has been found that for a 2 to 2.5 inch outer diameter filter, rated between about 2 and about 70 microns, the apertures **18** should consume about 2.5 percent of the area of each of sheets **16c**, and should consume about 1.25 percent of the area of each of sheets **16b**.

A first end of the sheet of the diffusion medium **20** is secured to the core **12**, using heat bonding for example, and the sheet is wound about the core to create a first or

innermost layer of the diffusion medium. The sheet of diffusion medium **20** and the sheets of filter medium **16a, 16b, 16c** are then coiled together about the innermost layer. The sheet of the diffusion medium **20** is longer than the sheets of the filter medium **16a, 16b, 16c** such that the sheet of diffusion medium will form an outermost layer around the filter medium. The outermost layer of the diffusion medium **20** is then secured to the adjacent layer of diffusion medium, using heat bonding for example, such that the filter is tightly and securely wound. Surprisingly, it has been found that winding the layers tightly does not affect either the removal efficiency or the dirt capacity of the filter **48**.

Example II:

Referring to **Fig. 8**, a second example of a filter **50** according to the present disclosure is shown. The filter **50** includes a single continuous sheet of diffusion medium **20** comprising thirty thousandths of an inch (**30** mils), bi-planar strand orientation (**17** mil strand size), twelve strands per inch, polypropylene extruded netting. The Side-to-Height Ratio of the diffusion medium **20** is approximately **4:1**. The filter material, which comprises melt-blown, non woven polypropylene micro fibers, is provided in a plurality of discrete sheets **16a, 16b, 16c, 16d**.

The sheets of filter medium **16a, 16b, 16c** exhibit substantially equal and consistent pore size and fiber geometry. Sheet **16a** does not have bypass apertures, while outer sheets **16b, 16c** have bypass apertures **18**. The outermost sheet **16c** of filter material is preferably provided with more numerous bypass apertures **18** than the intermediate sheets **16b**. Most preferably, the sheets **16b, 16c** are perforated in a manner substantially similar to the corresponding sheets of **Fig. 7**.

Sheets **16d** comprise melt-blown, non woven polypropylene micro fibers that are calendared, i.e., compressed between two rollers. Prior to being calendared, sheets **16d** have an substantially identical fiber geometries to the fiber geometries of sheets **16a, 16b, 16c**. In the calendering process, to the extent the dimensions of the fibers are affected, the fibers assume a greater dimension in the plane of the sheet **16d**. As a result, after being calendared, the sheets **16d** have a reduced pore diameter as compared to sheets **16a, 16b, 16c**.

As shown, prior to the filter **50** being coiled, sheet **16a** is placed under sheet **16d** adjacent sheet **16b**. After being coiled, the filter **50** includes: 1) inner layers of filter medium (innermost sheet **16d**) having a reduced pore size, 2) intermediate layers of filter medium (laid over sheets **16a** and **16d**) that have a pore size that alternates between a relatively smaller and larger size, and 3) outer layers of filter medium (sheets **16b** and **16c**) that have a relatively larger pore size.

Example III:

Referring to **Fig. 9**, another filter cartridge **70** according to the present disclosure is shown. The filter cartridge **70** is similar to the filter cartridge **10** of **Fig. 7**, and elements that are the same have the same reference numerals. The filter cartridge **70** includes a filter **72** having alternating layers of filter medium **74** and diffusion medium **76**.

The filter medium **74** has bypass apertures formed from bores **78** extending from an outermost layer **80** towards an innermost layer **82** of the filter. The continuous bores **78** each extend to a uniform depth within the filter **72**. Preferably, the bores **78** extend continuously to between about fifty and eighty-five percent (50% - 85%) of the radial distance from the outermost layer **80** to the innermost layer **82** of the filter **72**. More

preferably, each of the bypass bores **78** extends continuously to about sixty-six percent (66%) of such radial distance. It should be noted that the filter medium of the filter cartridge **70** can be provided with bypass apertures formed by bores continuously extending from an outermost layer **80** towards an innermost layer **82** of the filter, but to non-uniform depths within the filter **72**.

A method for manufacturing the cartridge **70** generally includes winding or coiling the sheet of the diffusion medium **76** and the sheet(s) of the filter medium **74** into alternating layers extending between the innermost and the outermost layers **82, 80**, and piercing the layers from the outermost layer towards the innermost layer to produce the multiplicity of bypass bores **78** in the filter. The bypass bores may be created by piercing the outermost layer **80** of the filter **70** with one or more elongated, narrow, sharp instruments, such as steel pins. A multiplicity of parallel steel pins, for example, are mounted on a flat base, and the filter cartridge **70** is simply pushed onto the spikes and pierced to create the bypass bores.

Example IV:

Referring to **Fig. 10**, a further filter cartridge **110** according to the present disclosure is shown (filter cartridge **110** is not shown with end caps; as will be readily apparent to persons of skill in the art). The filter cartridge **110** is similar to the filter cartridge **70** of **Fig. 7**, and elements that are the same have the same reference numerals. The filter cartridge **110** includes a filter having a single continuous sheet of diffusion medium **20** and at least one sheet of filter medium **16a** wound around a core **12**. The filter **110** also includes strips of filter medium **114** wound within the sheet of diffusion medium **20** between the sheet of filter medium **14** and the outer diameter of the filter. The strips **114** are spaced apart to create gaps that comprise bypass apertures **116**.

As shown, the strips of filter medium **114** are arranged longitudinally with respect to the core **12**, but the strips can be oriented in other directions, such as diagonally with respect to the core. The strips **114** are equally spaced apart from one another such that the resulting bypass gaps **116** are of substantially equal size. Alternatively, the strips can be spaced such that the resulting bypass gaps become larger towards the outer diameter of the respective filters, for example. It has been found that a filter cartridge **110** of the type disclosed in **Fig. 10** provides about the same improved performance as provided by the filter cartridge **10** disclosed in **Fig. 7**.

The presently disclosed filter cartridges can be used in a variety of end uses, including, but not limited to, chemical and hydrocarbon applications such as polyethylene manufacturing, food and beverage applications, electronic applications such as circuit board construction, coating applications such as high quality spray painting, and industrial applications such as paper manufacturing. It should be noted that while the examples of filters disclosed herein are elongated tubes with cylindrical cross-sections, filters in accordance with the present disclosure can be provided in other suitable configurations, such as elongated tubes with a square, elliptical, or oval cross-sections.

The filters and methods according to the present disclosure have been described in detail in the foregoing specification, with specific examples provided. Filters and methods in accordance with the present disclosure, however, are not to be construed as limited to the particular examples shown, as these examples are regarded as illustrious rather than restrictive. Moreover, variations and changes may be made to the exemplary filters by those skilled in the art without departing from the spirit of the present disclosure as set forth by the following claims.

What is claimed is:

1. A filter comprising:

a) alternating layers of filter medium and diffusion medium;

b) the diffusion medium including,

a first plane of spaced-apart, substantially parallel strands defining first longitudinal passages having a first height dimension and a first width dimension,

a second plane of spaced-apart, substantially parallel strands defining second longitudinal passages having a second height dimension and a second width dimension, the strands of the second plane being oriented in a non-parallel manner with respect to the strands of the first plane such that the first and the second planes define lateral openings having side dimensions,

wherein the first and the second longitudinal passages include at least one dimension that is smaller than any of the side dimensions of the lateral openings; and

c) at least one of the layers of filter medium comprising a pre-qualifying filter medium layer having bypass apertures.

2. The filter of Claim 1 wherein the pre-qualifying layers of filter medium extend from an outermost layer of the filter towards an innermost layer of the filter.

3. The filter of Claim 2 wherein the pre-qualifying layers of filter medium extend from the outermost layer towards the innermost layer to between about fifty percent and eighty-five percent of the distance between the outermost layer and the innermost layer.

4. The filter of Claim 3 wherein the pre-qualifying layers of filter medium extend to between about sixty-six percent of the distance between the outermost layer and the innermost layer.

5. The filter of Claim 1 wherein the bypass apertures of the pre-qualifying layer of filter medium are formed from bores extending from the outermost layer towards the innermost layer.

6. The filter of Claim 1 wherein the diffusion medium comprises extruded bi-planar netting.

7. The filter of Claim 6 wherein the diffusion medium is made from a thermoplastic.

8. The filter of Claim 7 wherein the diffusion medium is made from polypropylene.

9. The filter of Claim 7 wherein the diffusion medium is made from nylon.

10. The filter of Claim 7 wherein the diffusion medium is made from fluoropolymer.

11. The filter of Claim 7 wherein the diffusion medium is made from polyester.

12. The filter of Claim 1 wherein the filter medium comprises a fibrous mass of non woven fibers.

13. The filter of Claim 12 wherein the fibrous mass of non woven fibers is melt blown.

14. The filter of Claim 12 wherein the filter medium is made from a thermoplastic.

15. The filter of Claim 14 wherein the filter medium is made from polypropylene.

16. The filter of Claim 14 wherein the filter medium is made from nylon.

17. The filter of Claim 14 wherein the filter medium is made from fluoropolymer.

18. The filter of Claim 14 wherein the filter medium is made from polyester.

19. The filter of Claim 12, wherein at least a portion of the filter medium is calendered.

20. The filter of Claim 12 wherein the filter medium has a substantially constant pore size.

21. The filter of Claim 12 wherein the filter medium has a substantially constant fiber dimension.

22. The filter of Claim 1 wherein the filter medium comprises a porous membrane.

23. The filter of Claim 22 wherein the porous membrane filter medium is nylon.

24. The filter of Claim 1 wherein the filter medium comprises wet laid paper.

25. The filter of Claim 1 wherein:

the diffusion medium is comprised of one sheet;

the filter medium is comprised of at least one sheet; and

the sheet of diffusion medium and the at least one sheet of filter medium are coiled.

26. The filter of Claim 25 wherein the at least one sheet of filter medium is perforated near the outermost layer of the filter to comprise the pre-qualifying medium layer, with the perforations comprising the by-pass apertures.

27. The filter of Claim 25 wherein the at least one sheet of filter medium comprises a non-perforated qualifying layer nearest the innermost layer of the filter.

28. The filter of Claim 25 wherein the at least one sheet of the filter medium includes two non-perforated sheets that are layered prior to being coiled with the sheet of diffusion medium

29. The filter of Claim 28 wherein the layered non-perforated sheets have different average pore sizes.

30. The filter of Claim 25 wherein the at least one sheet of filter medium includes multiple sheets of filter medium having varied numbers of perforations, with the perforated sheets forming the pre-qualifying layers of filter medium and the perforations comprising the by-pass apertures.

31. The filter of Claim 1 further comprising an elongated, porous core around which the filter medium and the diffusion medium are wound.

32. The filter of Claim 31 wherein the diffusion medium comprises a single sheet secured at one end to the core, with the core being wrapped at least once with the diffusion medium.

33. The filter of Claim 1, wherein a plurality of pre-qualifying layers are defined and further wherein the bypass apertures vary in number as between at least two of said plurality of pre-qualifying layers.

34. The filter of Claim 1, wherein the ratio between the lesser of the side dimensions of the lateral openings and the greatest of the height dimensions of the first and second longitudinal passages is greater than 1.5:1.

35. The filter of Claim 34, wherein said ratio is about 4:1.

36. A method of filtering a volume of fluid comprising:

forcing a portion of the volume of liquid laterally through at least one pre-qualifying layer of filter medium, and a remainder of the fluid volume laterally through by-pass apertures in the at least one pre-qualifying layer;

re-mixing and passing the volume of fluid through a diffusion layer having lateral openings and longitudinal passages, wherein the longitudinal passages include at least one dimension smaller than any dimension of the lateral openings; and

forcing all of the volume of fluid laterally through at least one qualifying layer of filter medium.

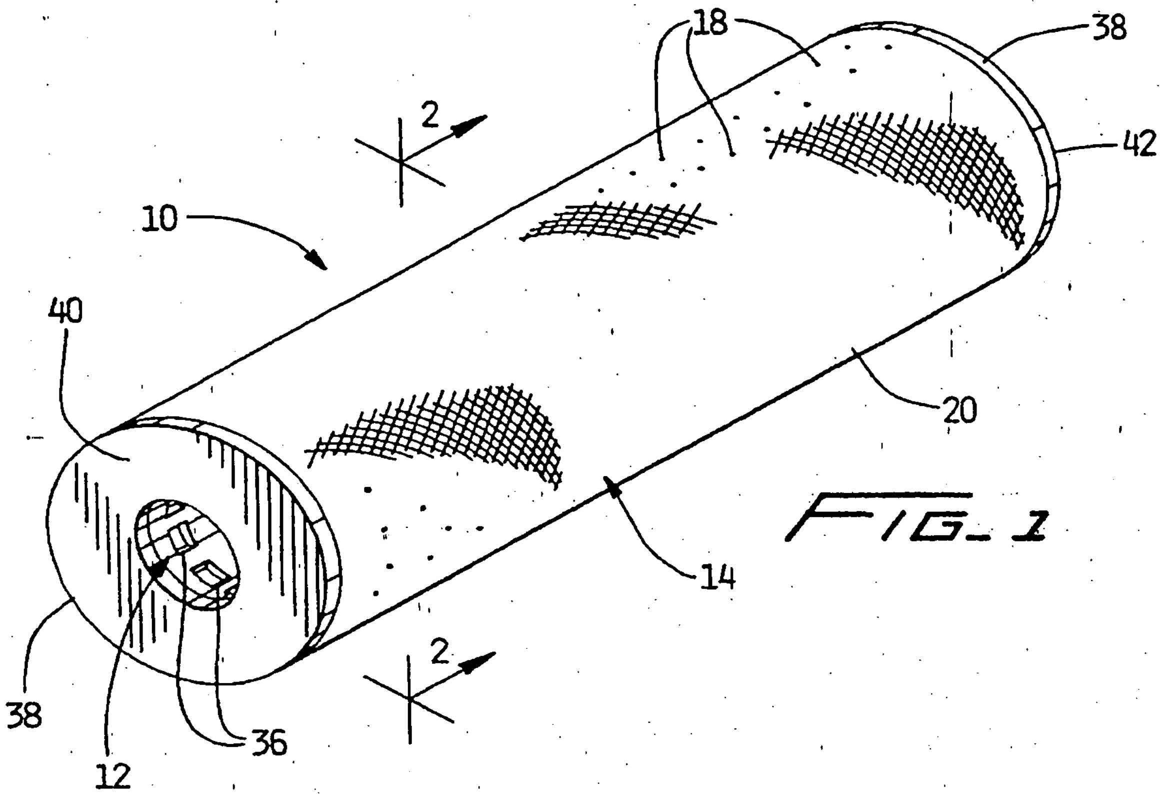


FIG_1

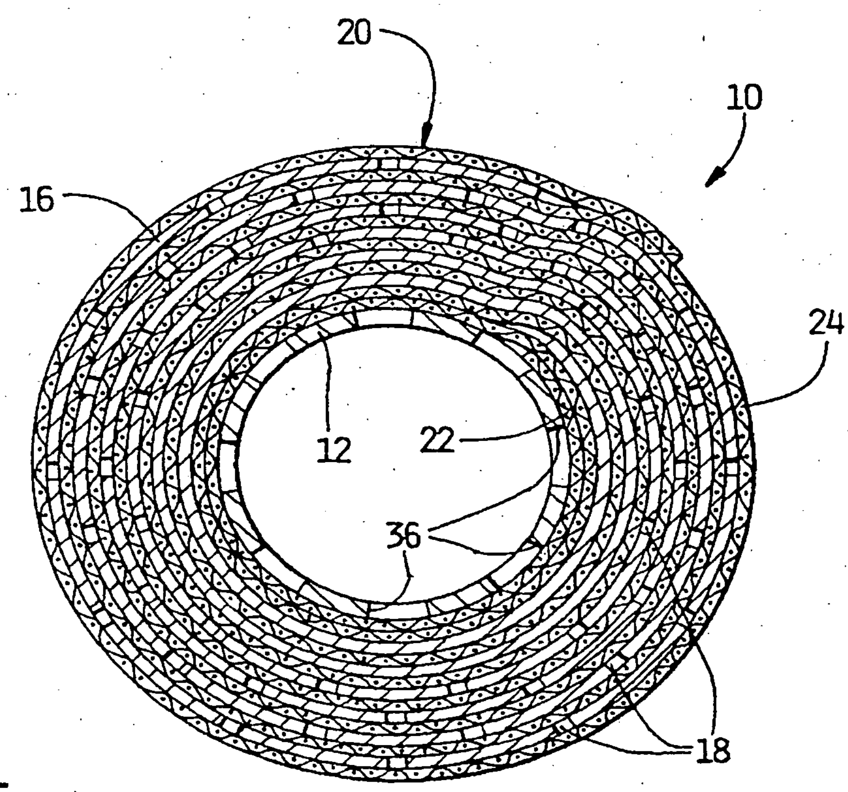


FIG_2

FIG_3

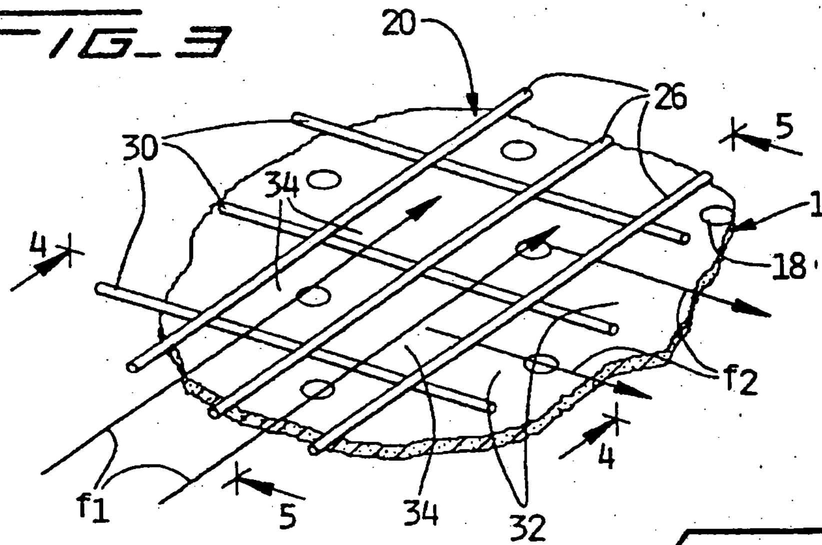


FIG_4

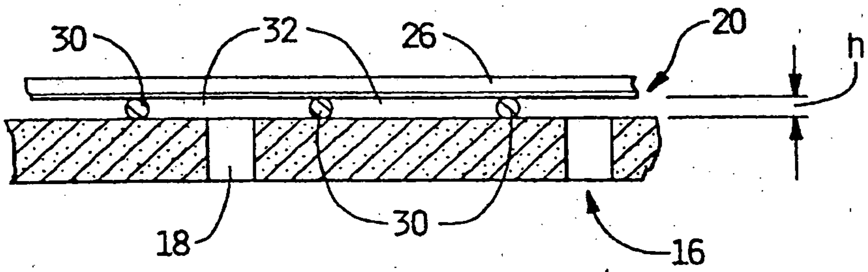


FIG_5

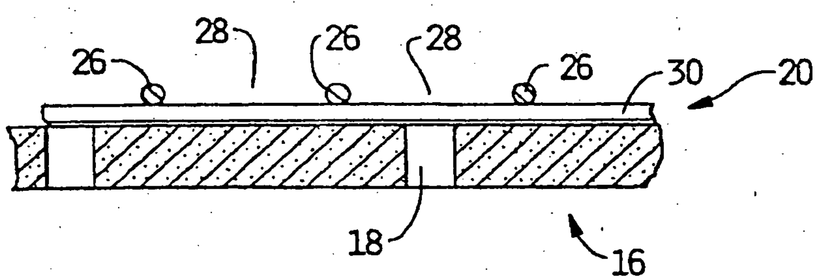
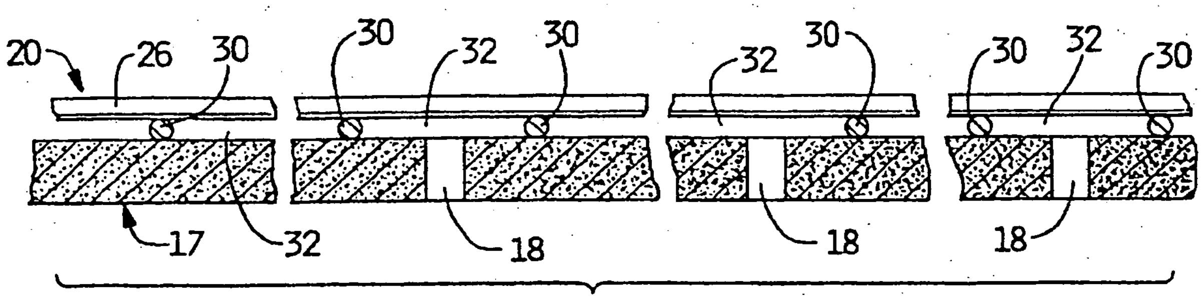


FIG_6



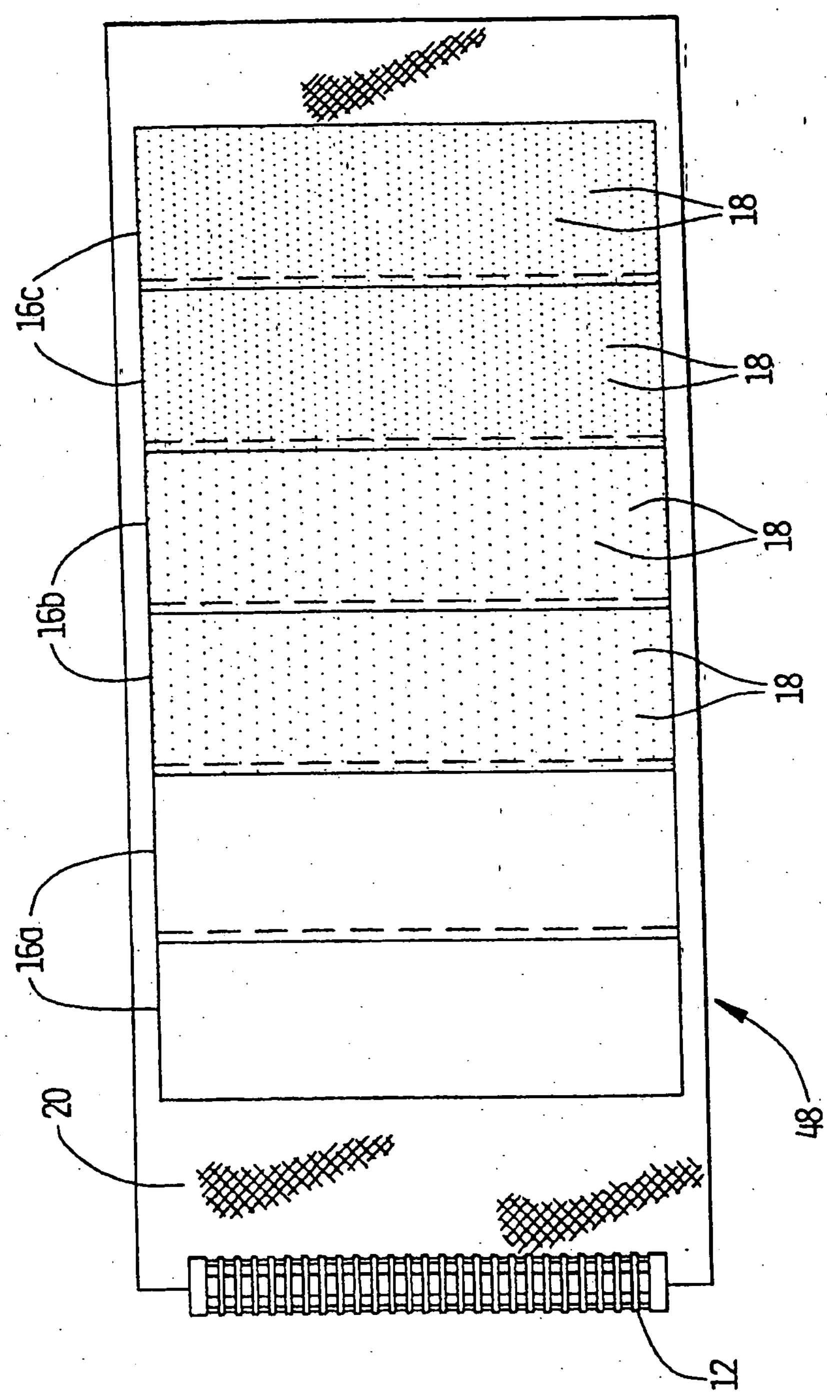


FIG. 7

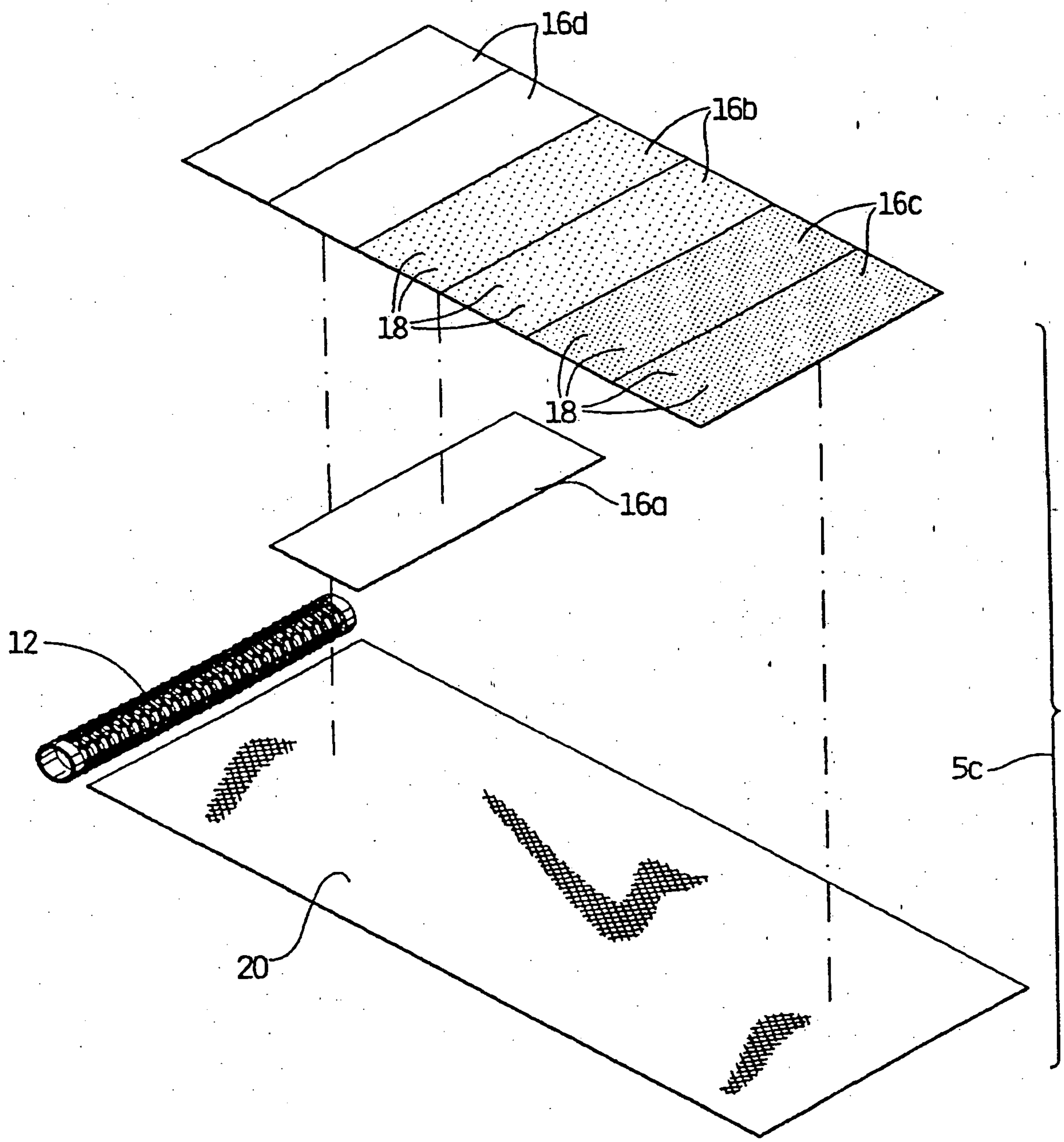


FIG_8

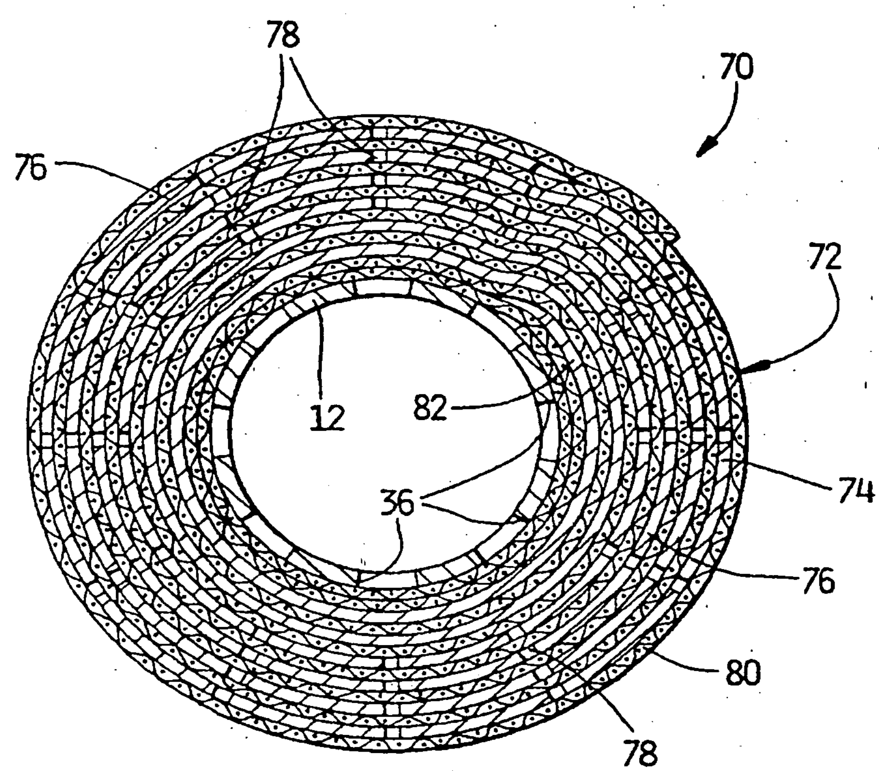


FIG_9

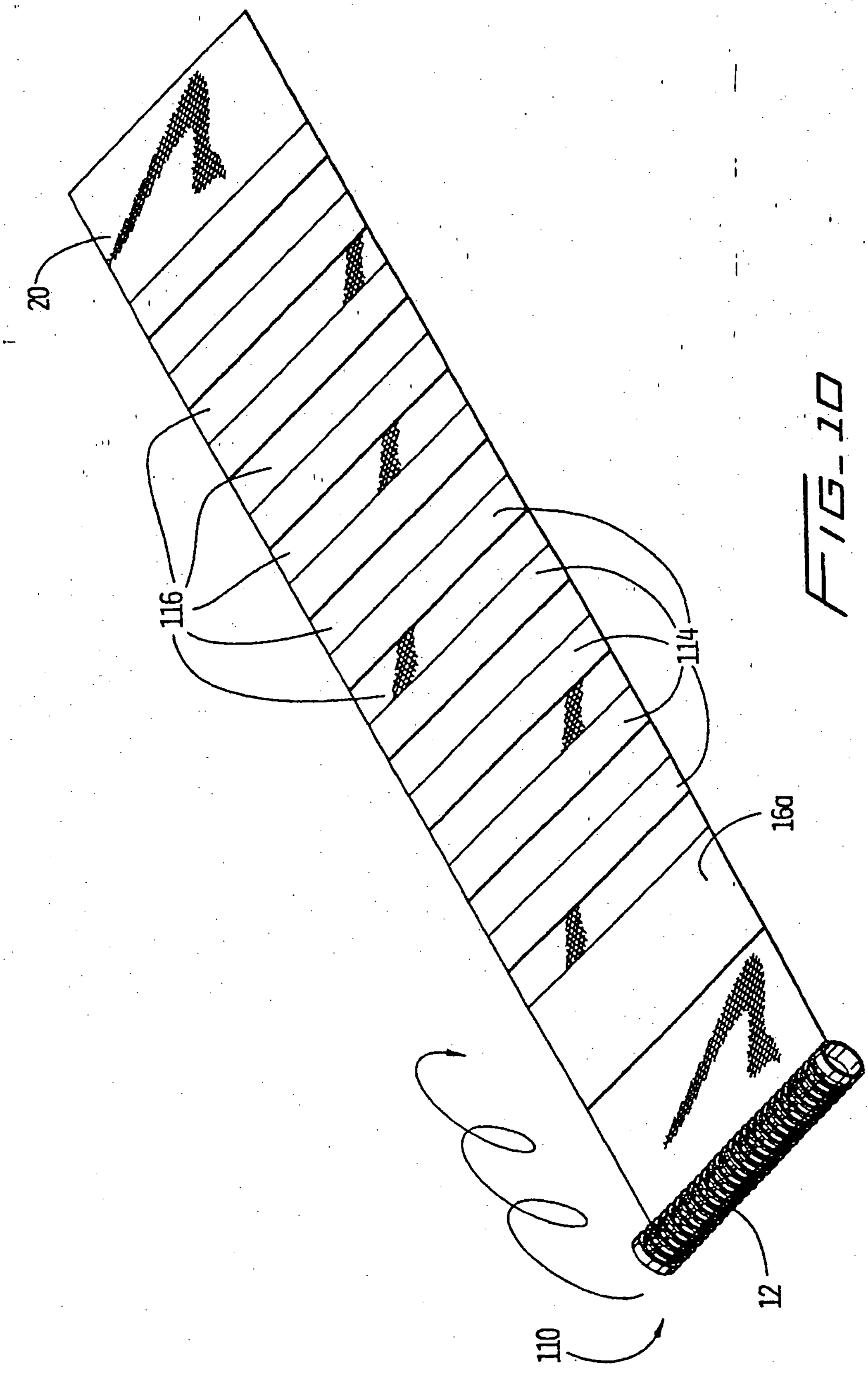


FIG_10

INTERNATIONAL SEARCH REPORT

Inter   onal Application No
PCT/US 99/23237

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B01D39/14 B01D27/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 306 231 A (MINNESOTA MINING & MFG) 8 March 1989 (1989-03-08) the whole document	1,2,5, 12-15, 25,36
A	US 4 062 756 A (JHA ANIL D ET AL) 13 December 1977 (1977-12-13) the whole document	1,6,7,22
A	WO 92 16281 A (KALTHOFF LUFTFILTER UND FILTER) 1 October 1992 (1992-10-01) page 5, line 11 - line 31; claim 1; figure 1	1,5,36
A	US 5 215 661 A (TANABE KAZUSHIGE) 1 June 1993 (1993-06-01) the whole document	1,2

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
24 January 2000	10/02/2000

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

Inter onal Application No
PCT/US 99/23237

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0306231 A	08-03-1989	US 4863602 A	05-09-1989
		AU 606448 B	07-02-1991
		AU 2101388 A	02-03-1989
		CA 1319626 A	29-06-1993
		DE 3875041 A	05-11-1992
		JP 1070119 A	15-03-1989
		KR 9700365 B	09-01-1997
US 4062756 A	13-12-1977	NONE	
WO 9216281 A	01-10-1992	DE 9102970 U	10-10-1991
		AT 124284 T	15-07-1995
		DE 59202697 D	03-08-1995
		EP 0533864 A	31-03-1993
		ES 2077405 T	16-11-1995
US 5215661 A	01-06-1993	NONE	